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Application of Different Biochar Sizes for Improving Chemical Properties of Sandy Soil and its Reflication on Yield Productivity

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ABSTRACT

The use of biochar as soil conditioner, either alone or in association with fertilizer, may be considered a specific management for improving the soil properties which adverse crops productivity. A field experiment was carried out in a sandy soil, winter season cultivated with lupine and summer season cultivated with peanut, to study the effectiveness of applying particle size of biochar at different depths to improve soil properties, nutritional status and yield components of crops. The experiment included four particle sizes of biochar S_1, S_2, S_3 and S_4 and three application depths D_1, D_2 and D_3. Results indicated that, generally, the application of biochar particle sizes with different application depths led to increase lupine and peanut yields as well as their total content of macronutrients as compared to control treatment. Also, application of 10 mm biochar at D_2 and 2mm biochar at D_1 were significantly superior for lupine and peanut yields along with their total content of macronutrients, respectively. Data showed that the application of S_1biochar and S_4 biochar were superior decreased of pH values in the first and second seasons, respectively. The electric conductivity and organic matter were increased gradually with increase of biochar particle sizes in lupine soil, while these parameters in peanut soil being decreased. In conclusion, application of biochar, with different sizes and depths, as soil conditioners led to improve soil chemical properties and increased fertility in sandy soil which reflected on both tested yield components along with their total content of macronutrients under conditions of experiment.

Keywords: Biochar, Particle size, Soil depth, Lupine plant, Peanut plant, Soil conditioners, Sandy soil.

INTRODUCTION

Agriculture is the lifeblood of both old and new so humans must in innovate and overcome the difficulties that may face us during agriculture such as high price of fertilizer and different chemical properties for soil types.

Biochar is defined as the solid substance resulting from thermochemical transfers of plant residues from various crops, bio-solids, and wood in an oxygen-neutral environment. (IBI, 2012). The authors added that biochar is a black, C-rich, stable. Recently, Biochar is also in agricultural applications for improving soil quality (Avanthi *et al*., 2015). Recent studies by Cong *et al.* (2017) found that biochar properties, from physical and structural strength to chemical and composition, depend on both the raw materials and thermochemical process used. In general, the original biomass structure strongly influences the final biochar structure, (Fuertes *et al*., 2010).

There are some factors that affect the effectiveness of biochar in soil, including: biochar properties (particle and pore size, surface area, porosity and surface functional groups) as well as soil properties (texture, pH and C content) and their complex interactions. biochar impacted significantly on soil properties, productivity of yields (Wu *et al*., 2017). Researchers have shown that biochar amendment significantly enhances the nutrient availability and nutrient retention of a wide range of soils. The soil fertility amelioration is achieved through improving soil physical, chemical, and biological properties in sandy soil (Hue, 2020).

Later on, Zhang *et al.* (2010) and Biederman and Harpole (2013) mentioned previously that biochar addition, generally, increased the yield of crop plants as well as enhanced soil carbon because the biochar acts as a stable C compound being degraded slowly, particularly to nutrient-deficient or drought-prone soils. The biochar acts as a soil conditioner, improving soil physical properties and nutrient use efficiency, thereby increasing plant growth. Also, the use of biochar could reduce chemical fertilizer use due to a reduced percolation of water and nutrients. Biochars would be able to hold nutrients and increase its availability to plant if they are applied in agricultural. Moreover, Biochar can increase microbial activity and reduce nutrient losses during composting which lead to the biochar charged with nutrients, covered with microbes and pH-balanced (Dias *et al*., 2010). Sukartono *et al.* (2011) revealed that biochar application increased soil organic carbon content and available N, P and K.

The used biochar after grind and sieved for reduce particle size enhanced mixing and surface contact between soils and particles, led to strong influence interactions between soil and biochar, since smaller biochar particles will necessarily have greater physical contact with soil particles (Chen *et al.* , 2017). Also, they suggested that biochar derived from smaller particles generally have higher ash content, which enhances liming effects and can increase nutrient and organic compound sorption. Liao and Thomas (2019) studied that biochar particle size effects on soil pH, water retention capacity and plant productivity. They found

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addition of biochar with smaller particle sizes will increased soil pH and will have stronger positive effects on plant growth, on the contrary, larger particle size increased soil water retention capacity.

Based on the previously mentioned information, the aim of this study is to evaluate the effect of different biochar particle sizes and adding them to different soil depths on some chemical properties of sandy soil and its reflection on both lupine and peanut productivity.

MATERIALS AND METHODS

A field experiment was carried out during two successive growing seasons cultivated with lupine (*Lupinus* L. Giza 1) at winter season (2019-2020) and peanut (*Arachis hypogaea* L. Giza 6) at summer season (2020) in a sandy soil under sprinkler irrigation system at Ismailia Agriculture Research Station farm (A.R.C) in Ismailia Governorate, Egypt. The institute farm is located at 30 35, 41.9" N latitude and 32 16 45.8" E longitude. Some physical and chemical characteristics of the experimental soil sites are shown in Table (1). As well as the characteristics of biochar using are shown in Table (2).

Table 1. Some physical and chemical properties of the experimental soil.

Soil characteristics	Values
Particle size distribution %	
Coarse sand	50.4
Fine sand	40.4
Silt	3.20
Clay	6.00
Texture class	Sandy
Chemical properties	
$CaCO_3$ %	1.40
pH (suspension 1:2.5)	7.92
EC dSm^{-1} (saturated paste extract)	0.37
Organic matter %	0.32
Soluble cations and anions (meq L^{-1})	
Ca^{++}	0.94
Mg^{++}	0.89
Na^{+}	1.45
K^{+}	0.45
CO^{-}	--
HCO_3	1.42
Cl^{-}	1.02
SO_4^{-}	1.29
Available nutrients (mg Kg^{-1})	
N	40.0
P	15.0
K	67.0

Table 2. Some chemical properties of biochar used in the experiment.

Characteristics	Biochar sizes			
	S1	S2	S3	S4
C%	82.48	77.1	75.53	69.98
N%	0.70	0.71	0.83	1.44
H%	1.35	0.11	2.45	0.83
S%	-	-	-	-
pH (1:2.5 soil: water suspension)	7.73	8.67	7.95	7.50
EC dS m^{-1} (1:5)	0.85	0.51	1.04	0.50
Available nutrients (mg Kg^{-1})				
N	46.7	20.5	49.0	32.8
P	35.0	19.0	70	40
K	3705	764	6337	4719

Experimental design and treatments:

The experimental design was a randomized split plot design, each treatment being replicated three times. The main plot was three application depth of biochar, (D):

1- 0-15 cm (D_1)
2- 15-30 cm (D_2)
3- 30-45 cm (D_3)

The sub main plot was four size of biochar (S)

1- 2 mm (S_1)
2- 5 mm (S_2)
3- 10 mm (S_3)
4- >10 mm (S_4)
5-Control (without biochar)

The dosage of biochar application (4% w/w)

Fertilizers application:

All treatments applied before cultivation and add the recommended fertilization rate for both lupine and peanut crops. Superphosphate (15 % P_2O_5) at a rate of 200 Kg $fed.^{-1}$ was added before cultivation; potassium was added in the form potassium sulfate (48 % K_2O) at 50 Kg $fed.^{-1}$, divided into two equal doses, the first was added at sowing and the second after 30 days from sowing. Nitrogen was applied in the form ammonium nitrate (33.5% N) at 350 Kg fed^{-1}, divided into four equal doses after 15, 30, 45, 60 days from sowing.

Examined parameters:

At harvest, plants were taken to evaluate yield components (straw and seeds) for both lupine and peanut crops. Plant samples were weighed and oven dried at 70 ^{0}C until constant dry weight, then ground and digested using H_2SO_4 and H_2O_2 mixture as described by Page *et al* . (1982). The digested samples were then subjected to the evaluation of nutrients (N, P and K) according to the method described by Cottenie *et al*. (1982) and calculated total content of nutrients in both straw and seeds of plants.

Soil samples were taken from different depths of soil, at the end of the growing season, were subjected for analysis of some soil chemical parameters according to Cottenie *et al*. (1982) as follow:

1- Electrical conductivity (EC) dSm^{-1} in soil water extract at ratio (1:5).
2- Soil pH was determined in 1:2.5 soil water suspensions.
3- Organic matter content (OM %).
4- Available N, P and K (mg Kg^{-1}).

Statistical analysis:

Obtained data were subjected to statistical analysis according to Snedecor and Cochran (1980) and the treatments were compared by using L.S.D. at 0.05 level of probability.

RESULTS AND DISCUSSION

Biomass yield and macronutrients total content:

Yield components:

Data presented in Table (3) showed that the yield components of lupine and peanut were increased significantly by applied different particle sizes of biochar (S) at all different depths (D) of soil as compared to control treatment. Addition of S_3 (10 mm) biochar at D_2 (15-30 cm) had a major to the increase in yield components (straw and seeds) of lupine yield, S_1 (2 mm) biochar at D_1 (0-15 cm) being the superior regarding peanut yields. Relative percentage, as compared to control, in yield components of lupine plants recorded 79.1 and 94.9 % for straw and seeds, respectively; while, for peanut plants recorded 91.9 and 97.2 %, respectively.

Table 3. Responses of lupine and peanut yields (Kg fed.$^{-1}$) to applied different sizes of biochar at different depths of soil.

Treatments		Lupine		Peanut	
Depth	Size	Straw	Seeds	Straw	Seeds
Control		1981	697	1758	895
D_1 (0-15 cm.)	S_1 (2mm)	2165	885	3375	1765
	S_2 (5mm)	2258	904	2195	1365
	S_3 (10mm)	2894	1135	2051	1283
	S_4 (>10mm)	2539	944	1913	1122
Mean		2368	913	2258	1286
D_2 (15-30 cm.)	S_1 (2mm)	2421	975	2983	1667
	S_2 (5mm)	2322	1153	2545	1446
	S_3 (10mm)	3548	1359	2316	1381
	S_4 (>10mm)	3296	1185	2144	1179
Mean		2514	1074	2349	1314
D_3 (30-45 cm.)	S_1 (2mm)	2589	926	2764	1520
	S_2 (5mm)	2655	960	2497	1409
	S_3 (10mm)	3130	1189	2297	1382
	S_4 (>10mm)	3119	1047	2226	1292
Mean		2494	964	2309	1300
Mean values of biochar sizes					
Control		1981	697	1758	895
S_1 (2mm)		2392	929	3041	1651
S_2 (5mm)		2412	1006	2412	1406
S_3 (10mm)		3191	1228	2221	1349
S_4 (>10mm)		2985	1059	2094	1198
LSD. at 0.05% for					
Depth (D)	A	540	59.5	269	148
Size (S)	B	395	55.8	259	178
Depth*Size	(AB)	684	96.7	449	308

These results are in good agreement with those obtained by Genesio *et al.* (2012) who found that biochar has been shown to promote plant productivity and yield through physical conditions change for biochar; its dark color alters thermal dynamics then led to facilitates rapid germination, allowing more time for growth compared with controls. Furthermore, Alaa *et al.* (2016) suggested that biochar addition to a sandy soil having coarse texture can lower water percolation through the soil and thus, conserve soil moisture for long time within the root zone, resulting in more availability of soil moisture and nutrients to plants, these lead to increasing plant growth and yield productivity.

Moreover, mean values of biochar addition at different soil depths can be arranged as D_2 (15-30cm) > D_3 (30-45cm) > D_1 (0-15cm) for straw and seeds at both two seasons. Moiwo *et al.* (2019) studied that effect of biochar application depth on the productivity of rice cultivar under tropical conditions. Biochar was applied in three depths 10 cm (TA), 20 cm (TB), and 30 cm (TC) with a non-biochar treatment (CK) as the control. The study showed that crop productivity increased, root penetration depth decreased with increasing biochar application depth. The total weight of plant was highest for TB, followed by CK, then TA and finally TC. Weight was not consistent along the treatments probably because of the negative effect of the field conditions, as changing of moisture content.

With respect to the effect of biochar particle size, data indicate that the application of S_3 (10 mm) biochar gave more significantly favorable yield components for lupine plants; in spite of that application of S_1 (2 mm) biochar was significantly superior for yield components of peanut plants.

Growth of peanut plants enhanced in soils with smaller-sized biochar particles, in contrast, lupine plants was grated in soils with large biochar particles. These data presented in Fig. (1) revealed that the yield components increased with increasing the particle size up to 10 mm then decreased at >10 mm for lupine, an opposite trend for peanuts which increased up to 2 mm after that decreased. These finding were observed by Liao and Thomas (2019). Thus, the biochar size may affect increasing growth and yield productivity through biochar's porous structure, capacity and allow for the retention of nutrients, (Novak *et al*., 2009)

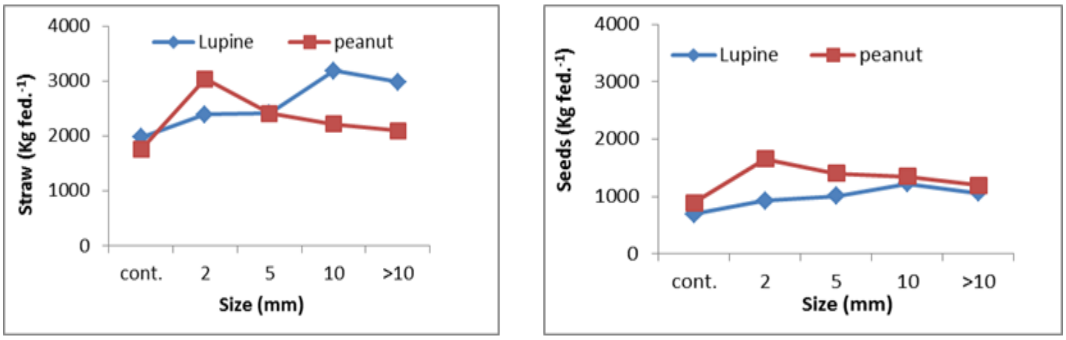

Fig 1. Responses of lupine and peanut yields (Kg fed.$^{-1}$) to applied different particle sizes of biochar.

Total content of macronutrients:

Regard to the total content of macronutrients for lupine and peanut crops results in (Tables 4 and 5) revealed that, generally, the application of different treatments of biochar gave significant positive effect on total content of macronutrients in straw and seeds for both lupine and peanut plants as compared to control. Such results are confirmed by those of Adriano *et al.* (2005) who found that addition of biochar can certainly have a positive influence on N and P nutrient uptake by increasing the sorption capacity. Warnock *et al.* (2007) added that biochar serves as a catalyst that enhances plant uptake of nutrients and water compared to other soil amendments due to its high surface area and porosity which enable it to adsorb or retain nutrients and water and increasing plant uptake of nutrients. Also, Major (2009) reported that biochar enhance nutrients values as a soil amendment; furthermore, biochar retain nutrients against leaching.

Furthermore, Schahczenski (2010) reported that biochar has low nutrients content but acts more as a soil conditioner by making nutrients more available to plants and improving soil structure. Moreover, pore structure of biochar likely provides a habitat for soil microorganisms, which in turn may aid in making nutrients available to crops, Also, the availability of N, P and K increased significantly, as expected, by increasing the rates of N and P fertilizers in presence of biochar. Plant growth can also be affected by biochar-induced changes in soil nutrient conditions, particularly the cycling of P and K (Dempster *et al.*, 2012 a, b; Taghizadeh-Toosi *et al.*, 2012).

Table 4. Macronutrients total contents (Kg fed.$^{-1}$) of both straw and seeds of studied lupine crop as affected by applied different sizes of biochar and depth of application.

Treatments		Straw			Seeds		
Depth	**Size**	**N**	**P**	**K**	**N**	**P**	**K**
Control		17.3	1.54	2.06	30.2	6.89	3.61
D_1 (0-15 cm)	S_1 (2mm)	19.2	5.81	2.28	41.3	8.11	4.89
	S_2 (5mm)	20.5	6.70	2.74	44.6	9.21	5.52
	S_3 (10mm)	40.9	7.36	3.85	57.3	14.6	7.66
	S_4 (>10mm)	25.2	9.93	3.11	47.4	10.5	6.25
Mean		24.6	6.27	2.81	44.2	9.86	5.59
D_2 (15-30 cm)	S_1 (2mm)	21.1	3.79	2.33	44.9	11.1	6.32
	S_2 (5mm)	21.2	4.37	2.50	54.0	14.4	9.17
	S_3 (10mm)	41.8	10.6	5.67	80.5	17.8	12.7
	S_4 (>10mm)	35.1	8.27	4.87	60.7	15.2	10.2
Mean		27.2	5.67	3.21	54.0	13.1	8.40
D_3 (30-45 cm)	S_1 (2mm)	22.8	2.60	2.78	44.9	9.68	5.25
	S_2 (5mm)	23.7	3.43	3.12	47.1	11.0	6.25
	S_3 (10mm)	32.9	6.18	4.01	62.2	15.2	9.60
	S_4 (>10mm)	28.9	5.34	4.39	54.1	12.5	8.11
Mean		25.1	3.77	2.99	47.7	11.1	6.56
Mean values of biochar sizes							
Control		17.3	1.54	2.06	30.2	6.89	3.61
S_1 (2mm)		21.0	4.07	2.46	43.7	9.63	5.49
S_2 (5mm)		21.8	4.83	2.78	48.6	11.5	6.98
S_3 (10mm)		38.5	8.05	4.51	66.7	15.9	9.99
S_4 (>10mm)		29.7	7.85	4.12	54.1	12.7	8.19
LSD. at 0.05% for:-							
Depth (A)		3.74	3.63	0.67	2.87	2.13	1.88
Size (B)		5.28	2.60	0.75	5.46	1.84	1.44
Depth*Size (A*B)		9.15	4.51	1.30	9.45	3.18	2.49

Table 5. Macronutrients total contents (Kg fed.$^{-1}$) of both straw and seeds of studied peanut crop as affected by applied different sizes of biochar and depth of application.

Treatments		Straw			Seeds		
Depth	**Size**	**N**	**P**	**K**	**N**	**P**	**K**
Control		24.6	5.54	26.0	34.1	4.53	9.45
D_1 (0-15 cm.)	S_1 (2mm)	65.9	18.2	67.0	92.2	24.4	39.5
	S_2 (5mm)	36.8	8.88	44.9	64.1	14.8	27.9
	S_3 (10mm)	32.1	8.16	43.3	60.3	12.6	23.6
	S_4 (>10mm)	29.7	6.47	30.8	49.3	12.8	18.4
Mean		37.8	9.45	42.4	60.0	13.2	23.8
D_2 (15-30 cm.)	S_1 (2mm)	52.1	16.9	95.5	89.6	16.3	41.2
	S_2 (5mm)	42.1	13.6	90.2	75.6	11.7	35.4
	S_3 (10mm)	37.8	8.45	61.5	65.1	10.3	34.8
	S_4 (>10mm)	34.0	7.72	53.8	49.6	7.35	26.7
Mean		38.1	10.4	65.4	62.9	10.2	29.5
D_3 (30-45 cm.)	S_1 (2mm)	50.3	14.1	87.9	84.3	16.2	32.9
	S_2 (5mm)	43.3	11.7	73.6	67.0	11.1	28.5
	S_3 (10mm)	39.5	9.70	53.6	65.2	10.1	25.4
	S_4 (>10mm)	34.8	8.99	47.2	55.7	8.45	24.0
Mean		38.5	9.99	57.7	62.1	10.0	24.1
Mean values of biochar sizes							
Control		24.6	5.54	26.0	34.1	4.53	9.45
S_1 (2mm)		56.1	16.4	83.5	88.7	18.9	41.3
S_2 (5mm)		40.7	11.4	69.6	68.9	12.5	30.6
S_3 (10mm)		36.5	8.77	52.8	63.5	11.0	27.9
S_4 (>10mm)		32.8	7.73	43.9	51.5	9.53	23.1
LSD. at 0.05% for:-							
Depth (A)		9.32	1.95	11.6	10.4	4.07	5.49
Size (B)		6.36	1.46	8.17	12.9	3.86	8.99
Depth*Size (AB)		11.0	2.52	14.1	22.4	6.68	15.6

Application of S_3 (10 mm) biochar at D_2 (15-30 cm) was significantly superior to macronutrients (N, P and K) either in straw and seeds of lupine crops. The corresponding straw and seeds of peanut, application of S_1 (2 mm) biochar at D_1 (0- 15 cm) as well as D_2 (15-30 cm) was significantly superior to N and P as well as K, respectively.

Generally, addition of biochar on depths can arrange as follows: D_2 (15-30 cm.) > D_3 (30-45 cm.) > D_1 (0-15 cm.) for both straw and seeds of lupine and peanut yields. Also, the behavior of the total macronutrients content followed the same trend of those recorded by yield components.

Irrespective of effect of biochar particle sizes, values of NPK total content for straw and seeds of lupine were significantly more stimulated with application of S_3 (10 mm) biochar. An opposite trend was encountered for straw and seeds of peanut plants whose values were significantly highest when application of S_1(2 mm) biochar.

Moreover, results in (Fig., 2) revealed that the nutrient total content increased with increasing the particle size up to 10 mm then decreased at >10 mm for lupine, an opposite trend for peanut which increased up to 2 mm after that decreased, these trend similar those recorded of yield components.

Manyà (2012) found that the particle sizes of biochar can impact biochar resistance to mineralization. Sigua *et al.* (2014) added that a biochar particle size > 2 mm was more stable than a particle size < 0.42 mm. A similar finding was reported by Zimmerman (2010); biochars < 0.25 mm had a higher mineralization rate than did 0.25 to 2 mm biochars. Ponomarenko and Anderson (2001) reported that the biochar adsorption capacity of soil clays depended on the particle size of the biochar. Particle-size dependent processes in soil-biochar systems may alter soil microbial processes directly or indirectly.

Moreover, results showed that the total content of both N and K in straw and seeds for peanut (second season) were gradually increase compared to lupine (first season). This may indicate that the availability of nutrients from biochar was higher with time goes. Adriano *et al*. (2005) who found that increasing the addition of biochar can certainly have a positive influence on N and P nutrient uptake by increasing the sorption capacity. De Gryze *et al.* (2010) also opined that biochar decreases the possibility of nutrient losses in soils and enhances nutrient recycling, resulting in positive impacts on crop yields in the long run through slow release to the soil. Also, Kizito *et al*. (2019) found that the increase available N, P, and K concentrations for plants as resulted of applied biochar enriched with nutrients.

Chemical properties of soil after lupine and peanut crops harvested.

Soil pH.

Comparing the pH values of the sandy soil and biochar used in the research (shown in Table 1, 2, respectively) if was found that the biochar practical sizes used in this study had a means pH values of 7.96 which is slightly higher than those of the soil which had a pH values of 7.92 and was lower than that of the biochar by 0.04 pH unit.

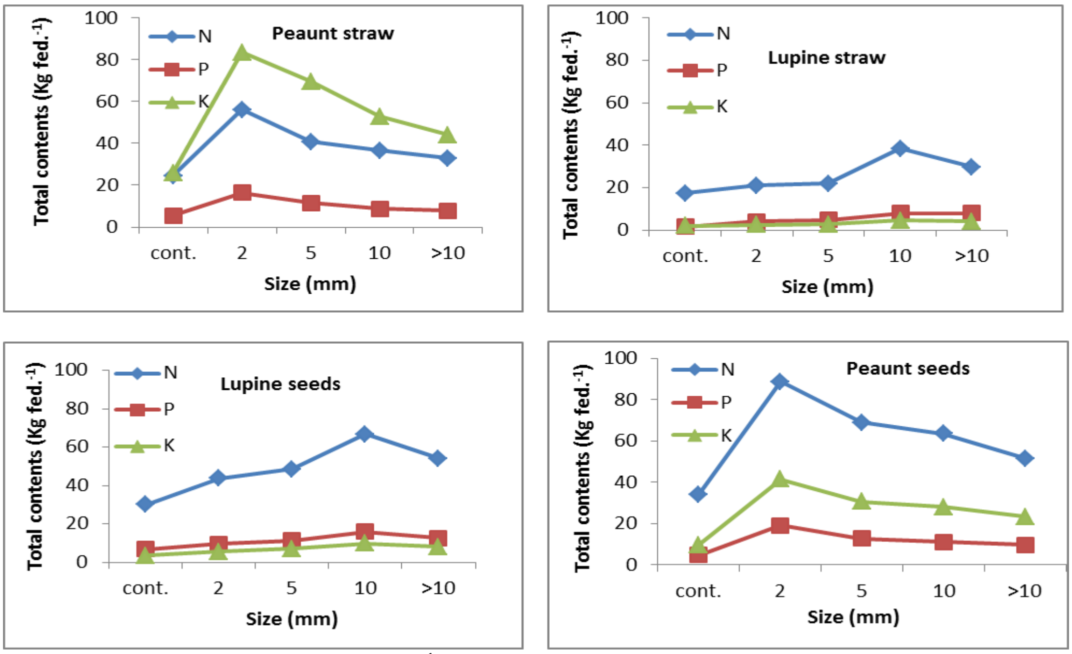

Fig. 2. Macronutrients total contents (Kg fed.$^{-1}$) of both straw and seeds of studied lupine and peanut plants as affected by different particle sizes of biochar under different depth of soil.

Table (6) shows the pH values after application of the biochar in the different practical sizes to different depth of soil. Soil pH was slightly inferior gradually as affected by applied biochar practical sizes as compared to control; this trend was true for both seasons. All treatments in soil of lupine led to decrease rate was within (0.01 – 0.16) pH units, in spite of that the decrease rate was within (0.01 – 0.24) for soils peanut. Application of S_1 (2 mm) biochar and S_4 (> 10 mm) at D_2 (15– 30 cm) was inferior to pH values for soil of lupine and peanut, respectively. This may be due to the presence of biochar practical sizes which governs the soil pH values, according to the production of organic acids formed as a result of biochar decomposition and oxidation. Also, obtained data agree with the results reported by Liu and Zhang (2012) who showed that application of alkaline biochar (pH 8.4) to alkaline soils (pH 8.7– 9.0) decreased soil pH by up to 0.2 units after 4 months of incubation. The pH reduction was enhanced with increasing biochar application rate and incubation time, most likely a result of the production of acidic materials from biochar oxidation.

In addition, increased soil acidic material production may be due to the low soil pH in the biochar treatments. Biochar can be oxidized, especially at the surface, through chemical and microbial activity (Cheng et al., 2006 and 2008).

Besides, they found that slow oxidization of biochar in soils can produce carboxylic groups. Biochar with organic matter in soils will increased the oxidation , which could also produce acidic groups, these acidic groups can finally decrease soil pH (Liang et al., 2010, Luo et al., 2011 and Zavalloni et al., 2011).

Regarding application of biochar at different depths, the results showed that the D_2 (15–30 cm) gave a decrease in soil pH as compared to the other depths for both seasons. Generally application of biochar on depths can be arranged as follows: D_2 (15– 30 cm) > D_1 (0–15 cm) > D_3 (30–45 cm) for both tested soil crops. Liu and Zhang (2012) reported that the application of alkaline biochar did not increase the soil pH but instead produced a decreasing pH trend. The decrease in soil pH was more significant at the 10 to 20 cm. layer than in the 0 to 10 cm. layer.

Table 6. Response of some chemical properties of the tested soil after lupine and peanut crops harvested as effected by applied different sizes and soil depth of biochar

Treatments		Lupine			Peanut		
Depth	Size	pH	EC (dSm^{-1})	OM %	pH	EC (dSm^{-1})	OM %
Control		7.84	1.11	0.64	7.69	1.04	0.53
D_1 (0-15 cm.)	S_1 (2mm)	7.70	1.28	0.78	7.62	1.41	0.85
	S_2 (5mm)	7.76	1.31	0.82	7.56	1.35	0.79
	S_3 (10mm)	7.82	1.13	0.96	7.53	1.29	0.78
	S_4 >10mm)	7.83	1.36	0.88	7.49	1.10	0.78
Mean		7.79	1.24	0.82	7.58	1.24	0.75
D_2 (15-30cm.)	S_1 (2mm)	7.68	1.07	0.66	7.58	1.25	1.14
	S_2 (5mm)	7.70	1.48	0.89	7.55	1.21	0.98
	S_3 (10mm)	7.75	1.55	0.99	7.52	1.13	0.66
	S_4 (>10mm)	7.79	1.48	0.91	7.45	1.09	0.60
Mean		7.75	1.34	0.82	7.56	1.14	0.78
D_3 (30-45cm.)	S_1 (2mm)	7.76	1.21	0.77	7.69	1.21	1.23
	S_2 (5mm)	7.80	1.32	0.81	7.68	1.16	1.17
	S_3 (10mm)	7.81	1.43	0.85	7.52	0.96	1.16
	S_4 (>10mm)	7.83	1.36	0.82	7.49	0.94	1.05
Mean		7.81	1.29	0.78	7.61	1.06	1.03
Mean values of biochar sizes							
Control		7.84	1.11	0.64	7.69	1.04	0.53
S_1 (2mm)		7.71	1.19	0.74	7.63	1.29	1.07
S_2 (5mm)		7.75	1.37	0.84	7.59	1.24	0.98
S_3 (10mm)		7.79	1.37	0.93	7.52	1.13	0.87
S_4 (10mm)		7.82	1.40	0.87	7.48	1.04	0.81
LSD. at 0.05% for							
Depth (D) A		0.11	0.30	0.079	0.09	0.27	0.064
Size (S) B		0.16	0.26	0.053	0.13	0.38	0.053
Depth*Size (AB)		0.28	0.45	0.092	0.23	0.67	0.092

With respect to the effect of biochar practical sizes, data showed that the application of S_1 (2 mm) biochar was superior decreased of pH values in first season, while S_4(>10 mm) biochar gives the high decreased of pH values in second season.

In the long term, the effect of particle sizes on soil microbial community structure can be expected to vary continuously in soils, since biochar continue to oxidize/ mineralize and alter soil physicochemical proper ties over time, these lead to changes in acidity of soil, (Yuan *et al*., 2017).

Electrical conductivity (EC).

The dissolved salt concentration (Electrical conductivity) measured in soil extract (1:5) at the end of the experiment are shown in Table (6). In general, EC insignificant increased as a result application of all the treatments of biochar particle sizes compared to control. The EC was higher at treatment of S_3(10 mm) biochar at D_2 (15-30 cm) and S_1 (2 mm) biochar at D_1 (0-15 cm), the most effective treatment for increasing salinity as compare to other treatments in first and second season, respectively. This may be due to presence of ash which is rich in basic cations during the reduction of char; also because of the positively and significant relationship between EC and exchangeable bases (Nigussie and Kissi, 2011).

The positive effects of application of biochar on different depths followed the order: D_2> D_3> D_1 for lupine soil, but followed the order: D_1> D_2> D_3 for peanut soil.

The electric conductivity increased gradually with increase of biochar particle sizes in lupine soil, in spite of the values decreased with increase of biochar particle sizes in peanut soil. This might be due to that having many negatively charged functional groups on the surface and increased CEC of soil, which makes biochar keeps nutrient cations, such as $NH4^+$, K^+, Ca^{2+}, and Mg^{2+} (Laird *et al*., 2010 and Wang *et al*., 2015).

Organic matter (OM).

Results in Table (6) reveal that the organic matter (OM) has significant increase due to the applied treatments compared to control at two seasons. The treatments of S_3 (10 mm) biochar at D_2 (15-30 cm) and S_1 (2 mm) biochar at D_3 (30- 45 cm) recorded significantly high increases in OM content of lupine and peanut soils, respectively. That increases were 0.99 and 1.23 % in lupine and peanut soils against 0.64 and 0.53 % for control treatment, respectively. These results are in conformity of work performed by Utomo (2010) and Sukartono *et al*. (2011) who found that the carbon and organic carbon content increased significantly over control with increased application of biochar to soil.

Also, OM content decreased with increases of applied biochar on depths in lupine soil, an opposite trend being for peanut soil which increased with increases applied biochar in depths. The high positive effects of biochar depths followed the order: D_1= D_2> D_3 and D_3> D_2> D_1 for lupine and peanut soil, respectively.

Furthermore, there is an opposite trend was encountered for application of biochar particle sizes treatments, whose values of OM content in lupine soil were increased with increases of particle sizes of biochar, in spite of that the OM content in peanut soil being decreased with increases particle sizes of biochar. The increase in soil organic carbon with application of biochar might have resulted from recalcitrant nature of carbon found in biochar which is largely resistant to decomposition (Lehmann et al., 2003).

Nutrients availability.

Data representing availability of soil N, P and K after lupine and peanut harvesting were showed in Table (7), their values increased due to the application of the treatments compared to the control treatment. However, the highest significant values of soil available N, P and K of 112, 20.5 and 108 mg Kg^{-1} in lupine soil against 126, 17.0 and 105 mg Kg^{-1} in peanut soil were due to applied S_3 (10 mm) biochar at D_2 (15-30 cm) for lupine soil and S_1 (2 mm) biochar at D_1 and D_2 for peanut soil.

Table 7. Responses of macronutrients availability (mg Kg^{-1}) for the tested soil after lupine and peanut crops harvested as affected by applied different sizes and depth of biochar

Treatments		Lupine			Peanut		
Depth	Size	N	P	K	N	P	K
	Control	93.0	7.57	50.7	100	5.80	71.1
	S1 (2mm)	98.5	10.4	54.6	126	17.0	102
D1	S2 (5mm)	105	12.4	58.5	119	13.8	94.3
(0-15 cm.)	S3 (10mm)	109	18.9	75.4	114	11.9	87.1
	S4 (>10mm)	106	15.7	63.1	112	7.37	83.2
Mean		102	12.9	60.5	114	11.2	87.5
	S1 (2mm)	98.1	10.4	61.1	119	16.8	105
D2	S2 (5mm)	109	17.7	88.4	116	9.40	102
(15-30 cm.)	S3 (10mm)	112	20.5	108	114	7.50	98.8
	S4 (>10mm)	107	18.5	103	112	7.20	96.2
Mean		104	14.9	82.2	112	9.34	94.6
	S1 (2mm)	95.7	9.5	56.6	121	16.4	79.3
D3	S2 (5mm)	98.0	13.6	61.1	112	10.1	78.3
(30-45 cm.)	S3 (10mm)	103	19.9	79.3	109	7.17	76.3
	S4 (>10mm)	100	16.2	72.8	107	6.22	78.5
Mean		97.9	13.4	64.1	110	4.44	76.7
Mean values of biochar sizes							
Control		93.0	7.57	50.7	100	5.80	71.1
S1 (2mm)		97.4	10.1	57.4	122	16.7	95.4
S2 (5mm)		104	14.6	69.3	115	11.1	91.5
S3 (10mm)		108	19.8	87.7	112	8.86	87.4
S4 (>10mm)		104	16.8	79.6	110	6.93	85.9
LSD. At 0.05% for							
Depth (D)	A	3.99	2.96	11.6	8.41	1.94	14.9
Size (S)	B	4.79	2.74	13.8	9.15	1.59	9.35
Depth*Size	(AB)	8.29	4.74	23.9	15.9	2.75	16.2

Regarding the applied of biochar on different depths, results indicated that the D_2 (15-30 cm) was generally superior for nutrient availability for lupine soil, while for peanut soil being superior when applied of biochar at D_1 (0-15 cm) for N and P as well as applied of biochar at D_2 (15-30 cm) for K.

To differentiate between the influence particles sizes of biochar, results showed that the S3 (10 mm) biochar was significantly higher than the other particle sizes for improving the nutrients availability in lupine soil. On the other hand, the applied S1 (2 mm) biochar treatment had significantly increased nutrients availability in peanut soil. Also, the behavior of nutrients availability in both lupine and peanut soils followed the same trend of those recorded by nutrients total content in straw and seeds in both crops.

The application of biochar to soil caused a significant increase in nutrients availability, through increasing the adsorption sites and nutrient availability. Available N, P and K due to applied of biochar to soils along with natural or synthetic fertilizers. Lehmann *et al*. (2003) demonstrated the ability of biochar to retain applied fertilizer against leaching with resulting increase in fertilizer- use efficiency. So, biochar usually has greater sorption ability than natural soil organic matter due to its greater surface area, negative surface charge and charge density, (Liang *et al*., 2006). Biochar can not only efficiently remove many cationic chemicals ions, but also sorb anionic nutrients such as phosphate ions (Lehmann, 2007). Biochar would be able to hold nutrients and increase its availability to plant if they are applied in agricultural fields (Zhang *et al*., 2010).

Biochar can be a good source of K for crop uptake, especially in organic farming, this is because more than 50% of the total potassium in it is dissolved in water and bioavailable (Berek *et al*., 2018). Recently, Karimi *et al.* (2020) added that the responses of the nutrient availability to biochar application depend on the addition rate and pyrolysis temperature; with increasing the biochar application rate, P and K availability were increased. In general, addition of corn residue biochar significantly increased soil organic carbon, microbial biomass, and respiration as well as the catalase and dehydrogenase activity, which could be beneficial in low fertility arid soils.

To make the picture clear to express the obtained results as linear correlation between seeds yield and studied parameters (OM, N, P and K availability) were showed in Figs. (3 and 4). In this study, a significant positive linear correlation were found between OM and seeds yield (R^2= 0.955 and R^2= 0.964) for lupine and peanut yields, respectively. The same trend was observed between N, P and K availability in soil and seeds of lupine and peanut (R^2 = 0.990, R^2= 0.990 for N, R^2 = 0.978, R^2 = 0.965 for P and R^2 = 0.968, R^2 =0.997 for K), respectively. This indicated the positive effect between the studied parameters and seeds yield productivity for both lupine and peanut yields.

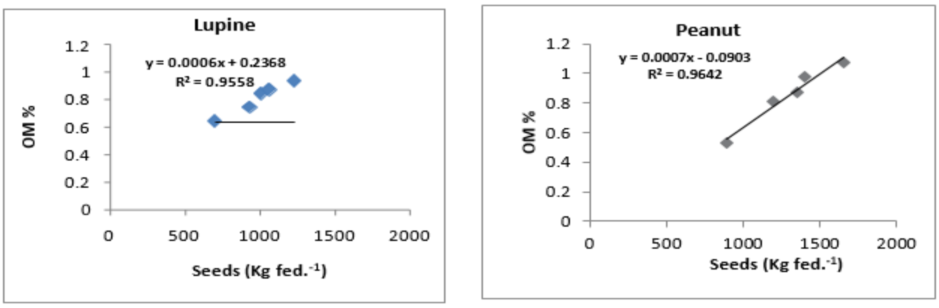

Fig 3. Relationships between organic matter of the tested soil after harvested and seeds of lupine and peanut crops.

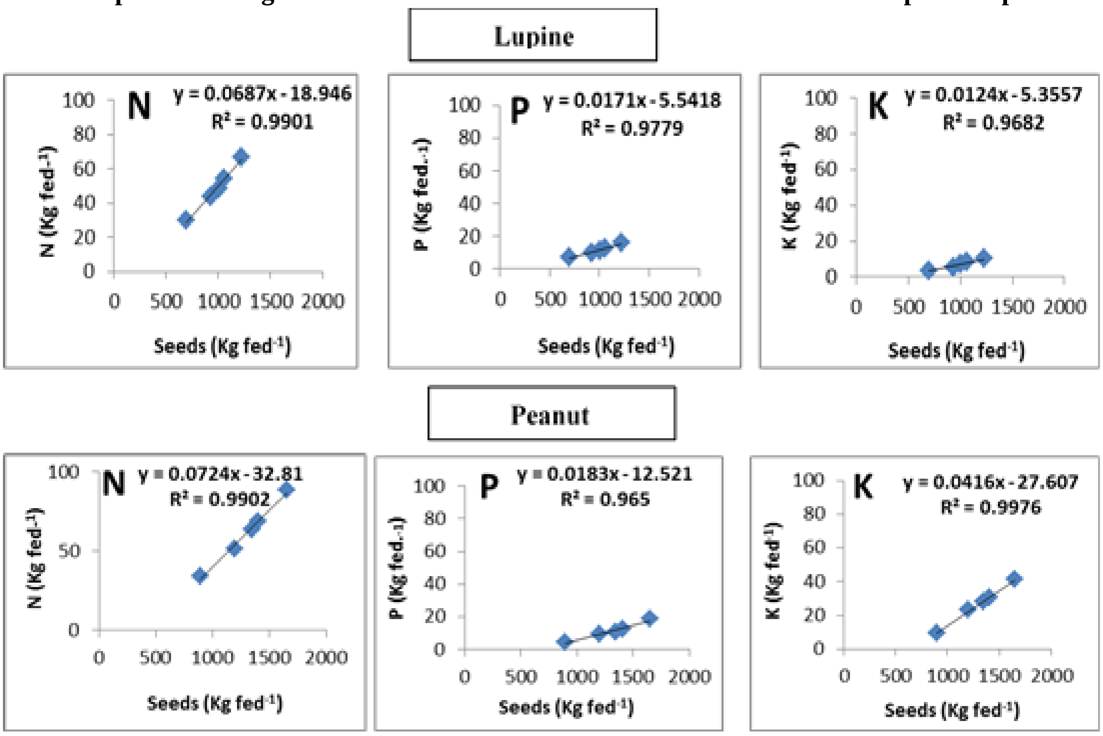

Fig. 4. Relationships between macronutrients total contents (Kg fed.$^{-1}$) of the tested soil after harvested and seeds of lupine and peanut crops.

CONCLUSION

Biochar is material can be used as a soil amendment to enhance soil quality. Addition of biochar to soil has many environmental and agricultural benefits, including waste reduction, water resource protection, and soil improvement. Therefore, the use of biochar as a soil amendment is an innovative and highly promising practice for sustainable agriculture. In this study, various sizes of biochar were used on different sandy soil depths. Lupine and peanut were cultivated as tested crops to determine the efficacy of biochar application on soil and crop productivity.

In conclusion, application of biochar with different sizes and soil depths as soil conditioners, in general, led to improved soil chemical properties (i.e. decreased soil pH, increased organic matter content) along with increased macronutrients availability (N,P, K) in sandy soil which reflected on both tested yield components (lupine and peanut) along with their total content of macronutrients under conditions of experiment.

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اضافة احجام مختلفة من الفحم النباتى لتحسين الخواص الكيميائية للتربة الرملية وانعكاسه على إنتاجية المحصول

سوزان على السيد ، جيهان حسنى يوسف ، هناء عطية زين العابدين وايمان محمد عبد المقصود

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يعتبر الفحم النباتى من محسنات التربة عند اضافته للارض سواء منفردا او مرتبطا بالأسمدة، لتحسين خواص التربة الرملية والتى تنعكس على انتاجية المحاصيل. لذلك أقيمت تجربة حقلية فى الارض الرملية بمزرعة البحوث الزراعية بالاسماعيلية، محافظة الإسماعيلية، خلال موسمين متتاليين. تم زراعة الترمس صنف (*Lupinus* L. Giza 1) خلال الموسم الشتوى (2019-2020) و زراعة الفول السودانى صنف (*Arachis hypogaea* L *Giza* 6) خلال الموسم الصيفى (2020)، لدراسة التأثيرات المختلفة لاحجام الفحم النباتى عند اضافته على أعماق مختلفة لتحسين بعض الخواص الكيميائية للتربة و حالة العناصر بها و مكونات المحصول لكل من محصولى الترمس و الفول السودانى. تضمنت التجربة أربعة أحجام مختلفة من الفحم النباتى S_1, S_2, S_3, S_4 والتى تمثل (2و 5 و10و أكبر من10 مم ، على التوالى) واضافتهم فى ثلاثة أعماق D_1, D_2, D_3 (صفر -15 و15-30 و 30-45 سم) على التوالي. أشارت النتائج بشكل عام أن اضافة الفحم النباتى بأحجام مختلفة وعلى أعماق مختلفة أدى إلى زيادة محصولى الترمس والفول السوداني بالاضافة الى محتواهما الكلى من العناصر الكبرى (النتروجين والفوسفور والبوتاسيوم) مقارنة بمعاملة الكنترول. أيضا، اضافة الحجم S_3 (10 مم) من الفحم النباتى على عمق D_2 (15-30 سم) و اضافة الحجم S_1 (2 مم) من الفحم النباتى على عمق D_1 (0-15 سم) اظهر زيادة معنوية على محصولى الترمس والفول السوداني و محتواهما الكلي من العناصر الغذائية الكبرى، على التوالي. فيما يتعلق بتأثير الأحجام المختلفة للفحم النباتى على بعض الخواص الكيميائية ، أظهرت النتائج أن أضافة الفحم النباتى (S_1) اظهرت انخفاضا لقيم الـ pH في الموسم الأول ، بينما اضافة الفحم النباتى (S_4) أدى الى انخفاضًا أكبر في قيم الـ pH في الموسم الثاني. اما بالنسبة لقيم التوصيل الكهربائى (EC) والمادة العضوية (OM٪) زادت تدريجياً مع زيادة أحجام الفحم النباتى في أرض الترمس. على العكس من ذلك ا ظهرت انخفاضا لقيم EC و OM٪ مع زيادة أحجام الفحم النباتى فى أرض الفول السودانى. بخصوص تأثير المعاملات المختلفة من الفحم النباتى على تيسر العناصر الغذائية الكبرى فى التربة عند كل من الموسميين، أخذت النتائج نفس الاتجاه السابق لمحتوى العناصر الكبرى فى النبات في الختام ، فان أضافة الفحم النباتى بالأحجام المختلفة و على اعماق مختلفة كمحسن للتربة أدى إلى تحسين الخواص الكيميائية للتربة وزيادة خصوبة التربة الرملية التى تنعكس على كل من مكونات المحصول بالإضافة الى محتواها الكلي من العناصر الكبرى تحت ظروف هذه التجربة.